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Technology Transfer Model for Small-Scale Farms

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Abstract: Small-scale farms make an important contribution to food security, but they lack technification, especially in the global south. This article proposes a new model, namely, Model H, as a reference by which to facilitate technological transfer and appropriation in small producer sectors. Starting with the identification of interactions with the environment and the characterization of the transfer and appropriation process with respect to information and communication technologies, a five-stage framework is established to create and validate the new model. Based on key elements, functionalities, and five variables identified as a common ground for the transfer and appropriation of technologies, Model H is presented as a five-layer, user-centered model that aims to include in the transfer and appropriation of the solutions of all the individuals and entities that participate throughout the process. The model is validated through a pilot test using an intelligent irrigation technology called AgroRIEGO. In the process of technology transfer and appropriation, this pilot study helped to identify implementation obstacles and the importance of knowledge management as an effective channel for the exchange of information in a pertinent and timely manner.

Keywords: small-scale farm; technology appropriation; technology transfer model

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1. Introduction

Agriculture is considered one of the most relevant economic activities for humanity; it is a primary food source with high nutritional value for humans and animals [1,2]. Best practices need to be identified and a plan needs to be developed to promote technological transfer and appropriation in the agriculture sector [3]. Hence, potential technological transfer and appropriation in the agricultural sector should be determined, and based on this, goals, responsibilities, and monitoring strategies need to be established, and capacities need to be measured to manage resources and benefit from the new technologies [3].

The agriculture sector is a productive environment faced with significant challenges in relation to the use of knowledge, whether ancestral or gained through research activities [4]. Despite the sector experiencing a worldwide reconfiguration to the point that it was considered as a set of productive linkages that allow the creation of added value, it has not been able to develop its own enhanced structure to meet the challenges of a knowledge-based economy [5,6]. Considering this requirement, efforts have been made to establish guidelines to promote technological transfer and appropriation in the agriculture sector, with a clear focus on information and communication technologies (ICTs), such as those presented by [7–10]. This focus of the transfer and appropriation models on ICTs is due to the fact that these technologies enable communication and information processing in this process [11]. ICTs allow information and knowledge resources to be accessed regardless of location and context and support learning processes for the creation of knowledge and the development of thinking skills [11]. According to [12], technology transfer in the agriculture sector plays a crucial role in increasing farmers' productivity and income generation. Technology transfer further aids the development of mechanisms that promote technological transfer and appropriation among small-scale farms, in which a full picture is taken into consideration for the relevant and timely development of this process [13].

In order to identify various mechanisms depending on the context, various authors have proposed transfer models, such as [14], who presented a conceptual framework comprising a receiver who receives a message from a transmitter; this transmitter uses mechanisms to transfer data and knowledge of the transferred technology. In 2014, a model was presented in which governmental research institutions generate the technologies and private companies are the receivers [15]. The development of three (3) phases is highlighted in this model: Proof of concept, referring to the marketability of a technology; new technological development, as the process of generating a new technology, system, or procedure; and commercialization, as the process of transferring the technology. Similarly, [16] presented a technology transfer model for the information and communications industry in Libya. The key elements highlighted are as follows: government support for technology transfer, learning centers, the transferor, the transferee, the transfer process factor, and achievements related to technology transfer. Similarly, in 2016, the STAR model for technology transfer was proposed, which was based on four components: a provider, transfer tools, transfer barriers, and a transferee [17]. The transfer and appropriation process models present schemes where elements, such as a transmitter, a transmission channel, a receiver, and facilitating agents, are recognized but are presented separately and without any obvious articulation points.

There has not been an approach that enables the generation of a complete and articulated vision of the process of transfer and appropriation of ICT technologies based on the theory and practice. The development of isolated exercises generates different imaginaries about this process, thus limiting the possibility of identifying all related elements, players involved, and possible dynamics. It is necessary to develop a model that considers technology transfer and appropriation in the agricultural sector, which provides innovative solutions to small farmers [18]. The objective of this study was established to build a model that articulates transmitters, transmission channels, receivers, and facilitating agents, considering the existing dynamics between these elements for this sector [13]. This article is structured as follows: Section 2 describes the methodology used to build the model, Section 3 presents the model built, and Section 4 conducts validation based on an application case in a Colombian municipality. Finally, Section 5 presents the conclusions of the model application.

2. Materials and Methods

To contribute to the articulation of transmitters, transmission channels, receivers, and facilitating agents in the ICT transfer and appropriation scheme, a model was created to support the development of the small-scale agriculture sector. The model was built on the basis of a multi-methodology that combined techniques such as the systematic review of scientific and technological information, data mining, stakeholder analysis, future scenarios, and case studies. These techniques were used to identify the main elements needed to construct a model that would allow for the provision of mechanisms for the transfer and appropriation of ICTs. To define specific mechanisms for the agricultural sector, a case study was applied to the Colombian small-scale farmer sector.

The model was constructed in five stages. A systematic review of the scientific literature was performed to characterize the ICT transfer and appropriation process (Stage 1) and describe the reference practices (Stage 2). Subsequently, the actors involved in the ICT transfer and appropriation process were identified (Stage 3). Next, the model was formulated based on the elements identified in the previous stages (Stage 4). Finally, a pilot test of the model was conducted using a prototype for the implementation of AgroRIEGO technology in small-scale agricultural systems in the department of Santander, Colombia (Stage 5).

2.1. Stage 1: Characterization of the Process of Transfer and Appropriation of Information and Communication Technologies

Following the systematic evaluation of the scientific literature proposed by Tranfield [19], the scientific contributions registered in databases such as Premier, SAGE Knowledge, Springer Link, Oxford, IEEE Xplorer, Scopus, ScienceDirect, Google Scholar, and Taylor & Francis were considered for the study. The main elements for the ICT transfer and appropriation model and related practices were established and interconnections between these elements were identified. With this information the phases of the ICT transfer and appropriation process were determined by consensus: pre-submission, intellectual property disclosure, technology evaluation, strategy, protection, marketing, licensing, negotiation, commercialization, and loyalty.

2.2. Stage 2: Description of Reference Practices for the Transfer and Appropriation of ICTs

The review of scientific documents, institutional reports, case studies, news, videos, and other information sources allowed the identification of successful experiences at the national and international levels. From these experiences, best practices for the ICT sector were selected and described by a panel of experts.

Models such as Hamza's [20] present different actions associated with knowledge management and technology transfer, which imply the development of bonds of trust for effective communication. Among these actions are the media, awareness sessions, and community building. For their part, Novickis [21] presented a model in which the transfer comprises the layers of technology development, transfer support, and innovation, which imply the development of a minimum viable product, considering the monitoring of technologies, the connection with stakeholders, and user awareness. However, it does not present a clear and dynamic interaction between the processes for technology transfer and appropriation.

Hassan et. al. [16], proposed a model composed of elements of government support in technology transfer, learning centers, the transferor, assignee, the transfer process factor, and technology transfer achievements, characterized by the articulation with the stakeholders of the environment of the technology development process. Saini and Kumarkhurana [17] proposed the STAR model, in which how the provider sends the information and knowledge to the transfer tools is presented, where feedback is made to the provider while the information is sent to the receiver. This study made it possible to identify the barriers that can influence the communication of information and knowledge at any point of the transfer, evidencing the importance of the existence of the great environment. The model presented in [22] recognizes the importance of minimizing investment risks in the development of technologies, considering that at the same time, the economic growth and development of a country must be promoted. In this sense, elements related to organizational and management capacities in the transfer and appropriation of technologies are raised. At the same time, dissemination is considered relevant in appropriation processes.

2.3. Players Involved in the Process of Transferring and Appropriating ICT Technologies

The fundamentals of stakeholder analysis of strategic foresight were employed to identify the players deemed strategic for the transfer and appropriation of ICT technologies. Within the framework of this technique, current literature was used to identify the most frequently mentioned stakeholders. The players identified were classified according to the quadruple helix model, which contemplates the public, private, academic, and social sectors [23]. Subsequently, dynamics among these players were established considering convergences or divergences regarding the goals of technology transfer and appropriation.

2.4. Model H Construction

The characterization of the ICT transfer and appropriation process, which established the phases of the model, served as the foundation and framework for the building of Model H. Subsequently, considering the best practices and recognized players, transmitters, transmission channels, receivers, and facilitating agents were established with corresponding roles and dynamics.

2.5. Validation of Model H Based on a Pilot Test

A pilot test was conducted to establish the standards for the H model's scalability, reproducibility, and sustainability. The pilot test was related to the development of a case study in the Colombian small-scale farmer sector. Thus, the unit of analysis corresponded to a productive unit of a small-scale producer in the agriculture sector.

The case study was designed by establishing the main guidelines for data collection and primary and secondary information, and it was recorded using an application protocol. The protocol considered the establishment of the methods and techniques to be employed, and the instruments for data and information collection were constructed. Moreover, the critical points for data collection were established so that the transfer and appropriation elements of the model could be effectively evaluated. For the results analysis, observation and research techniques were applied to evaluate the transfer and appropriation of the considered solution.

Considering the approach of technology transfer and appropriation models toward ICT, the technological solution irrigation management system AgroRIEGO was considered. AgroRIEGO is a solution based on the Internet of Things (IoT), whose end user is a producer of the agriculture sector who needs to be aware of the water status of crops. Through a wireless network of sensors distributed throughout the crops, the irrigation management system collects information on soil moisture conditions in real-time. This information is complemented by weather conditions to generate recommendations on when and where to irrigate, according to crop needs.

3. Results

3.1. Elements of the ICT Transfer and Appropriation Models

Common elements of the ICT transfer and appropriation models were identified in this study: the sender, who develops the technology; the object being transferred, which is sent by the sender; and the transfer mechanisms, as the elements that allow the object to be transferred and appropriated by the receiver. Therefore, this study contributes to reducing the gap between the models developed for the transfer and appropriation of technologies, which are applicable to the small-scale farms sector. The elements provided by these models served as input when defining the elements that characterize the dynamics the Model H.

3.2. Model Functionality Features

Considering the importance of recognizing good practices for this process, among the criteria for establishing a good practice in this context, the analysis of existing models when developing a technology transfer model allowed for the following criteria to be determined: it should be effective, sustainable (complies with the triad: environmental, social, and economic), gender sensitive (considers men and women), and technically possible; it should be the result of a participatory, replicable, and adaptable process; it should reduce disaster risks; it should be transversal and should involve networking; and it should generate identity, allow for community evaluation, and generate an impact. Considering these criteria, technological dissemination, protection of the invention, commercialization of the invention, and technological adoption were defined as good practices.

3.3. Model Variables

The following variables were identified as determining the ICT transfer and appropriation process: (1) Technological appropriation, (2) Educational level, (3) Investments, (4) Technological adaptation, (5) ICT management, and (6) Technological capacity.

A total of 2350 players related to the ICT transfer and appropriation process were identified and classified according to their interests and/or lines of action. Each type of stakeholder was evaluated according to their convergence and/or divergence with respect to variables, such as long-term development goals, by using a power and favorability analysis. International regulatory entities and international companies were established as dominant players, thereby making it difficult to influence the decisions made in this type of organization.

Moreover, the users of technologies, communication channels, investors, suppliers of agricultural inputs, and national companies are located in a linkage zone, which indicates that they have an intermediate level of power and that although they have great influence over some players, they are dependent on others. As autonomous players, productive sector companies were identified, grouping small, medium, and large companies, which are considered to have minimal power in the system analyzed and thus have a low-level influence over others and limited dependence on others. Alternatively, within the dominated players are the governmental players, such as national government and regulation and governmental agencies, who consider the significant influence of foreign entities and the business sector while developing measures or establishing action mechanisms.

3.4. Model H

The elements identified in the established guidelines were articulated for the construction of the ICT transfer and appropriation model, known as Model H. The structuring of the model allowed for a general overview, a second overview considering the players related to the transfer and appropriation process, and finally a third overview considering the specific subprocesses.

The main guidelines for the construction of the model were determined, such as its user-centered design approach, under the double diamond scheme, and its construction in layers, as shown in Figure 1.

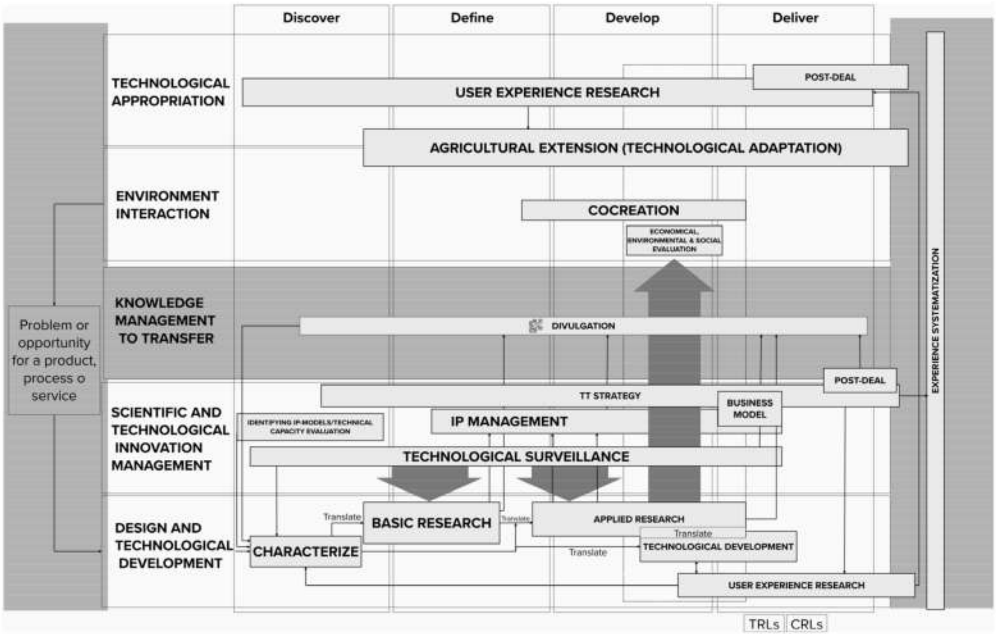

Figure 1. Model H for the transference and appropriation of technologies.

The user-centered approach is based on the importance of guaranteeing the transfer and appropriation of the solutions in the productive sector, considering users are the individuals and entities that participate throughout the process. The model is represented in a matrix of four stages (columns) by five layers (rows). To incorporate innovation and technological development in the definition of the problem or the need to be met, the double diamond scheme was considered with its four stages: Discover, Define, Develop, and Deploy. The layered representation made it possible to categorize the tasks by levels so that communication would be structured and fluid among the five layers of the model: (1) Design and technological development, (2) Management of scientific–technological innovation, (3) Knowledge management to transfer, (4) Interaction with the environment, and (5) Technological appropriation. Based on this layout, the model makes it simple to identify the point in the transfer process and the relationship between various stages and layers that conform to it. Knowledge management for transfer encompasses the entire model covering not only all stages but also the four remaining layers, thus obtaining an environment resembling an H, which gives the model its name.

Moreover, this model considers the existence of players as without them, there would be no real transfer of knowledge and technology. Thus, all players that are part of model H were mapped.

This model starts with two driving forces for technology transfer: Market Pull and Science Push. Market Pull identifies a problem generated by either new regulations, modifications, or repealed laws that change the context in which end users or companies have been developing. Science Push recognizes the optimization of processes and opportunities for improvement as in the case of technology-based companies and research centers. As there was a need to articulate the dynamics of each process and define its importance, a map of subprocesses was established based on the good practices identified during the execution of the previous stages, where there was a divergence between the academy and the transfer to the productive sector. This scheme lists each of the processes and determines the way they interact with others for technology transfer and appropriation to take place. The description of each of the layers is listed as follows:

- Design and technological development: This refers to the cocreation of technology based on the user, considering the concept, prototype, and innovative elements. It involves players such as knowledge generators, technology suppliers, associations, the state, and investors;
- Management of scientific–technological innovation: This considers the elements of technological innovation defined in the previous layer to adapt technology to a final product or service. It involves technological monitoring, technology packaging, intellectual property, and identification of opportunities/marketing channels for the product or service. Players such as technology transfer offices and research departments are involved;
- Knowledge management to transfer: This defines Model H and seeks to activate communication channels between the layers. It refers to the use of knowledge and information management techniques and the establishment of collaborative work networks;
- Interaction with the environment: This guarantees access and adaptation of technologies according to the user, considering the acceptance variables (trust and privacy, expectation of usefulness, expectation of effort, habits, and cost). It involves players such as extensionists and technology providers, associations, technology emissaries, and governmental entities;
- Technological appropriation: This allows for the evaluation of technology transfer and appropriation due to interaction with the user. It involves the participation of associations, extensionists, governmental entities, academia, and NGOs.

3.5. Validation of Model H

Model H was validated considering the guidelines of the case study methodology; thus, the phenomenon of ICT transfer and appropriation was studied within a specific context. This context corresponds to the scope established by the AgrIoT project, related to the Colombian small-scale farms sector, the development of IoT solutions for this sector, the culture of the region, and the characteristics of the territory of the department of Santander. The pilot test was executed over a six-month period considering the time frames set by the AgrIoT project. Given the general scheme, the pilot test allowed the validation of Model H based on the identification of the requirement through the development of the AgroRIEGO solution, according to the user's characteristics and the transfer of the solution to this same user.

Considering the model built, the pilot test was developed in the sector of Colombian small-scale farmers. An analysis of the agricultural sector focused on small-scale producers made it possible to identify the current status, trends, opportunities, and challenges for the political, social, environmental, economic, legal, and technological dimensions. From a political perspective, the rural population was identified as being vulnerable, and the policies promoting sustainability have not been consolidated. In economic terms, owing to the lack of policies to strengthen the agriculture sector worldwide, it is expected that the second sustainable development goal, "Zero Hunger," will not be achieved; thus, government entities should be more involved in the agriculture sector and increase the budget to promote research, development, and innovation (R&D&I). At a social level, a change was identified in the food diet due to changes in lifestyle, related to an awakening of awareness of the human being as an inhabitant of the planet and the need to increase productivity. Specifically, in Latin America, small producers have not adopted good agricultural practices to reduce waste, which is related to the incorporation of technological and innovative elements. From the environmental perspective, it was determined that climate variations have affected the sector's activity, causing damage to crops, affecting soil, and causing fire, among other changes. Thus, technological solutions have been implemented combined with ancestral knowledge to improve crop efficiency. At a legal level, ICT is one of the most important areas of knowledge for rural development in developed and undeveloped countries.

The characteristics of this group of technologies were explored considering that the solution to be incorporated for the development of the pilot test is associated with IoT. The IoT seeks to integrate the physical with the virtual, using the Internet as a means of communication and information exchange [24]. The IoT comprises a network of intelligent objects capable of self-management, information, data and resource sharing, decision-making, and action [24]. Based on this definition, and with the aim of identifying the potential of applying IoT technologies, a technology watch (TW) exercise was conducted in the small-scale farmer sector.

The purpose of this exercise was to identify the dynamics in the generation of knowledge and technological developments in IoT, the main players involved, and specific aspects for the sector under analysis. The TW, which was divided into three phases, aimed to gain a general understanding of scientific–technological developments in IoT, identify IoT trends and behaviors in agriculture, and identify IoT potentials specifically for the small-scale farmer sector. The results were validated by a panel of experts in the academic and productive sector associated with agriculture. Regarding TW for the general IoT, a growing trend was identified from 2010 to 2020, especially in logistics and transportation, with initiatives in health, agriculture, and supplies. In the small-scale farmer sector, the application potential of IoT technologies is focused on aspects related to the formulation, contextualization, and manipulation in the environment corresponding to the solutions.

Once the model was built and following recognition of the general trends of IoT technologies, the pilot test was developed at El Milagro farm, located in the district of El Salto, in the municipality of Simacota in Colombia. The players involved in the pilot test were the AgrIoT project researchers, family members of farmers living in the farm, and a spin-off company called Think Link involved in the development of technological solutions. Based on the first version of the AgroRIEGO solution, which did not follow any transfer-oriented design model, Model H was applied considering the results of the analysis of the small-scale farmer sector, the TW exercise, and analysis of related players. Consequently, a second version of AgroRIEGO was created, which considered the application of many elements of the model developed.

The configuration of the need and/or opportunity was established as per the validation requirements of Model H in the AgrIoT project, which were outlined in the terms of reference that became the requirements for the execution of the pilot test. From the contractual and operational viewpoint, a strategy was developed by the project team to validate each of the elements of Model H. The strategy involved presenting Model H to the company in such a manner that it would identify the guidelines for the generation of a new version of the AgroRIEGO solution according to the context to be studied. This generated an action plan in the developer company for the execution of activities considering the phases of Model H. Considering the development of user-centered solutions, Model H demonstrates the significance of including developers and users in the cocreation process of these solutions. Think Link's action plan contemplated a cocreation exercise considering users; however, the dynamics implied addressing several challenges.

Mental obstacles were identified by the developers based on their previous experiences that did not allow a relevant and timely exchange of information. These obstacles were related to sensitivity regarding the exchange of information that could be considered confidential, the AgroRIEGO solution, uncertainty about the intellectual property of the solution, and a thinking frame based on advanced technical language that is challenging to communicate to a multidisciplinary team, with the social elements in question. Although a relevant dynamic related to the work plan established by the developers was created, these obstacles hindered the combination of technology-based knowledge with farmers' ancestral knowledge.

The pilot test identified that, in the scheme designed for Model H, the technical execution for the development of the solution does not present major problems. However, throughout the scheme, there were obstacles related to the transmitter of the solution, which could not create effective transmission channels toward the receivers. This is due to mindset obstacles in the transmitters, who base the development of solutions entirely on technology-based knowledge. Thus, they do not favor or allow the incorporation of users' knowledge and due feedback. Although some elements presented by consumers were incorporated, the receivers or users did not manage to be a real propositional part of the cocreation process. Meanwhile, the developers or transmitters were involved in presenting a solution that they felt reflected the consumer's requirements with relevant technical execution.

The development of the pilot test also became an opportunity for the participating spin-off firm to validate its internal processes, from which the need to incorporate profiles from other fields was established. Additionally, raising awareness of the importance of considering different users' perspectives allowed the mobilization of cocreation and the incorporation of small producers as active agents in the process, thus positively appropriating the use of the AgroRIEGO 2.0 technological solution.

4. Discussion

The models on the ICT transfer and appropriation process have common elements, such as the transmitter, transmission channel, receiver, and facilitating agents; however, they are presented separately and do not have clear points of articulation. This disconnection, which does not allow a timely and effective transfer and appropriation of solutions, implies that a model needs to be rigorously applied to enable the articulation of different elements and their respective dynamics. Therefore, this study proposes a new model, namely, Model H, based on multiple methodologies that allows the identification of all the elements involved in the successful transfer of technologies for small-scale agriculture. Model H focuses on the generation of user-based innovations and seeks effective technological transfer and appropriation. This is considered to be of immense significance when no model with these guidelines has been identified.

The construction of the model implies that in the group of players participating in the ICT transfer and appropriation process, the users of the solutions are identified as liaison participants. Thus, users have a level of influence that determines the development of solutions, which justifies the user-centered approach. With respect to the productive units or companies, they are identified as autonomous players, which, in turn, implies that they neither have any influence in the process, nor are they influenced. This helps recognize that productive units are isolated from the process of technology transfer and appropriation.

It is essential that a technological transfer and appropriation model considers the entire typology of related players, the complexity of this process, and the large number of interactions that occur among players, whether between layers, stages, or subprocesses.

This is based on the fact that the nature of the transfer process and the purpose of Model H is to integrate the parties for relevant and timely communication. Among the most important players in technological transfer and appropriation are developers, as they are the ones who, in their context, can establish the communication links with end users, and in the face of possible blockages, eliminate the possibility of innovation.

The Knowledge management to transfer layer is the great differential of Model H based on the importance of a transversal communication channel that ranges from the inception of an idea to the delivery of the technology to the end user. This environment emerged as a result of the research on the construction of the model and was characterized and validated through the development of the pilot test. Specifically, it refers to the need to have a communication flow between layers and stages, which allows mobilizing processes and subprocesses, along with the promotion of adequate communication between related players.

Model H raises the importance of recognizing and quantifying the capabilities to mobilize the transfer process; however, the scope of the project did not include the construction of metrics to measure varied capabilities. Moreover, the model presents a characterization based on basic research, followed by applied research and subsequently technological development, with the option to pass through the model according to the line of action deemed relevant.

5. Conclusions

This paper proposes a comprehensive technology transfer model called Model H. This model focuses on the generation of user-based innovations and the articulation of the entire typology of related stakeholders, considering the complexity of technology transfer and appropriation and the interactions that occur among stakeholders, in such a way that relevant and timely communication is fostered. The model overcomes the disconnection identified between the transmitter, transmission channel, receiver, and facilitating agents of the technology transfer and appropriation models that does not allow the productive environment of small-scale farms to be energized. The validation of Model H shows the importance of the Knowledge management to transfer layer, as an effective channel for the exchange of information in a pertinent and timely manner, in the process of technology transfer and appropriation. Ignoring information provided by end users in the Design and technological development stage may cause technologies to be discarded by the user as they do not satisfy their real needs and do not fulfill the purpose of appropriation.

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